TITLE: **A monitor for showing high-resolution and three-dimensional images and method.**

This is a continuation-in-part of copending U.S. patent application Serial No. 09/611,541, filed July 7, 2000, the entire disclosure of which hereby is incorporated by reference. U.S. Patent Application Serial No. 09/611,541 claims priority of Provisional U.S. Patent Application No. 60/142,752, filed July 8, 1999 under 35 USC 119(e).

Technical Field

The invention relates generally to apparatus and method for displaying three dimensional images.

Background

Presently three-dimensional displays are based either on imaging techniques which give rise to an apparent stereo effect (also referred to as stereoscopic effect and/or three dimensional or 3D effect) by perspective views or on two images being presented that are separated such that the right eye and left eye see their respective images, which are distinguished or differentiated by polarization characteristics of light. Most of these displays are single purpose in that they are designed for the purpose of viewing stereo. Two images separated or distinguished by polarization can either be superimposed as they are with two movie projectors or they may be displayed time sequentially to give an image which appears to be continuous. Autostereo is another technique for presenting and viewing stereo images.

Many stereo display techniques are confined to using field sequential techniques which usually require very fast video switching thus needing a very rapid display or require two small displays worn in a headset. The field sequential methods or techniques are prone to flicker as the two images are

superimposed upon each other in time sequence and are viewed sequentially by respective eyes looking through shutter glasses or polarized glasses. The right image is expected to be viewed by the right eye of a person viewing the image (viewer) and the left image is expected to be viewed by the left eye. Part of the flicker problem is the high contrast between the right and left image, while those images are being presented which makes them flicker or at least to appear to flicker even at higher than normal frame rates. Also, a consequence is a reduction in bandwidth capability since the two images presented are normally in a standard bandwidth for two dimensions.

To try to reduce flicker, refresh rate, e.g., images per unit time, may have been increased in the past, but since the amount of image data may remain about constant, the amount of data per image may decrease, thus reducing resolution and possibly increasing flicker.

As a result of flicker, the viewing of 3D images can cause fatigue and reduced enjoyment and/or productive use of the 3D images.

There is a need in the art to improve the quality of displayed 3D images (sometimes referred to herein as three-D, three dimensional, stereo, and stereoscopic images (with or without the word "images" being used)). There also are additional needs in the art of 3D imaging, for example, to reduce flicker, to improve resolution and to make the 3D viewing experience more productive, less fatiguing, and more pleasant.

SUMMARY

One aspect of the invention relates to a display system comprising a pair of displays, each having a polarized light output, the polarization for both displays being the same, the displays being at an angle to each other, and a beam splitter so positioned relative to the two displays at the bisectrix of said angle to combine images from the displays whereby one image is transmitted by the beam splitter and the other image is reflected by the beam splitter to provide direct view of images from the displays such that the images can be separated based on polarization.

Another aspect relates to a method of displaying stereo images, comprising simultaneously displaying a left image on a display and a right

image on another display such that the left and right images have the optical polarization in the same direction, and using a beam splitter so positioned relative to the two displays that one can be viewed directly through the beam splitter and the other can be viewed by reflected light from the beam splitter combining those images in a common light path such that the optical polarization of the left image portion and the right image portion are different in such common light path such that the image portions can be separated based on optical polarization.

Another aspect relates to a method of presenting a stereoscopic image for viewing, comprising presenting a left eye image on a display, presenting a right eye image on another display that is at an angle relative to the first mentioned display, both said presenting steps presenting such images having optical polarization in the same direction, and using a beam splitter that is so positioned relative to the two displays combining in a substantially common light path the respective images such that the respective images in the common light path have different optical polarization, whereby the images can be separated based on polarization so that one image can be viewed directly through the beam splitter by one eye and the other can be viewed by reflected light from the beam splitter by the other eye.

Another aspect relates to a device for rotating the polarization direction of polarized light, comprising a source of linear polarized light that has a polarization direction at 45 degrees to a linear axis and is transmitted along an optical path, and a reflector in a plane that is parallel to and intersects the linear axis and oriented to reflect such linear polarized light, whereby the polarization direction of the reflected linear polarized light relative to the polarization direction of the linear polarized light prior to reflection is rotated 90 degrees about the optical path.

Another aspect relates to a method of rotating the polarization direction of linear polarized light that has a polarization direction at 45 degrees to a linear axis and is transmitted (propagates) along an optical path, comprising reflecting such linear polarized light using a reflector that is in a plane that is parallel to

and intersects the linear axis, whereby the polarization direction of the reflected linear polarized light relative to the polarization direction of the linear polarized light prior to reflection is rotated 90 degrees about the optical path.

Another aspect relates to a display system, comprising, a first display having optical polarization characteristics, a second display smaller in area than the first display and having optical polarization characteristics, the second display being at an angle to the first display, a beam splitter at the bisectrix of the angle between the first and second displays combining in superimposed viewable relation along a common light path images from the second display with images from a corresponding area of the first display by transmitting an image from one display and reflecting an image from the other display while rotating the plane of linear polarization or sense of circular polarized light.

Another aspect relates to a stereo display device, comprising a flat display having a polarized light output, and a beam splitter positioned relative to the display for transmitting light from one part of the display to a viewing area and reflecting light from another portion of the display to the viewing area while rotating the direction of plane polarized light or changing the sense of circular polarized light that is reflected, the light being provided along a common light path for viewing by discriminating based on polarization characteristics.

Another aspect relates to a stereo display comprising two image generators at an obtuse angle relative to each other and a beam splitter at the bisectrix of the obtuse angle.

Another aspect relates to a display system including a pair of displays, the displays being at an obtuse angle to each other, and a beam splitter so positioned relative to the two displays at the bisectrix of said angle to combine images from the displays whereby one image is transmitted by the beam splitter and the other image is reflected by the beam splitter to provide direct view of images from the displays.

To the accomplishment of the foregoing and related ends, the invention, then, comprises the features hereinafter fully described in the specification and particularly pointed out in the claims, the following description and the annexed drawings setting forth in detail certain illustrative embodiments of the invention,

these being indicative, however, of but several of the various ways in which the principles of the invention may be suitably employed.

Other systems, methods, features, and advantages of the present invention will be or become apparent to one with skill in the art upon examination of the following drawings and detailed description. It is intended that all such additional systems, methods, features, and advantages be included within this description, be within the scope of the present invention, and be protected by the accompanying claims.

Although the invention is shown and described with respect to one or more embodiments, it is to be understood that equivalents and modifications will occur to others skilled in the art upon the reading and understanding of the specification. The present invention includes all such equivalents and modifications, and is limited only by the scope of the claims.

Also, although various features are described and are illustrated in respective drawings/embodiments, it will be appreciated that features of a given drawing or embodiment may be used in one or more other drawings or embodiments of the invention.

Brief Description of the Drawings

In the annexed drawings:

Fig. 1 is a schematic illustration of a monitor for showing high-resolution and three-dimensional images using plane polarized light in accordance with the invention and of a viewer viewing such images;

Fig. 2 is a schematic illustration of a monitor for showing high-resolution and three-dimensional images using circularly polarized light in accordance with the invention and of a viewer viewing such images;

Fig. 3 is a schematic illustration of another embodiment of a monitor for showing high-resolution and three-dimensional images using circularly polarized light in accordance with the invention and of a viewer viewing such images;

Fig. 4 is a schematic illustration of an embodiment of monitor of the invention in folded condition;

Fig. 5 is a schematic illustration of the embodiment of monitor of the invention of Fig. 4, here shown in partly open condition;

Fig. 6 is a schematic illustration of the embodiment of monitor of the invention of Figs. 4 and 5, here shown in fully open condition;

Fig. 7 is a schematic illustration of a display system according to an embodiment of the invention;

Figs. 8A, 8B and 8C are schematic illustrations of an embodiment of the invention illustrating the reversal or inversion of images of one of the respective displays in the monitor of the invention;

Fig. 9 is a schematic illustration of a display system according to an embodiment of the invention including two displays in a cubical mount;

Figs. 10-15 are, respectively, side, front, isometric, back, top and bottom views of an over/under monitor arrangement;

Fig. 16 is a fragmentary isometric view of a windowed 3D monitor; and

Figs. 17 and 18 are schematic side elevation view and top plan view of another monitor using one display or two displays at a 180 degree angular relation.

Description

According to an exemplary embodiment, the invention includes two flat panel displays which are arranged at an angle relative to each other, for example, at 90 degrees or approximately 90 degrees and a beam splitter which is positioned at the bisectrix of the angle between the two displays. The angle at which the displays are arranged relative to each other may be different, e.g., larger than 90 degrees, for example, an obtuse angle. As an example of a bisectrix, consider two flat panel displays, the planes of which are parallel with the same linear axis; thus, for example, the two planes may be arranged similar to the front and back covers of a book, with the spine of the book representing the axis. The bisectrix would be an angle that bisects the angular relation of the two planes (displays or book covers); and, for example, the bisectrix would be a plane that also is parallel to the linear axis (e.g., like the book spine) and bisects the angle equally between the first two mentioned planes (e.g., the displays). As is described further below the images from both displays may be

viewed; and if the images provided thereby are, respectively, left and right eye images, which can be discriminated, e.g., by polarized lenses or some other means, a stereoscopic (3D) display (monitor) is obtained and stereo (3D) images produced thereby may be viewed.

If the flat panel displays are liquid crystal displays, the light output of each display will be polarized. The usual polarization direction for many active matrix displays, for example, is at 45 degrees to the edge of the display. This characteristic of such liquid crystal displays allows the present invention to be carried out with relative efficiency and minimum parts.

When linear polarized light is reflected from a surface that is in a plane which is perpendicular or transverse to the direction of incident light, it does so without a change in direction of polarization. However, if the reflecting surface (in this case the beam splitter) is set at an angle to the surface of one of the liquid crystal displays such that the reflected image changes direction by 90 degrees or approximately 90 degrees and the direction of polarization is at 45 degrees to the change of direction, the result will be that the linear polarized light will appear to have rotated 90 degrees. As an example, consider two adjacent flat panel displays, each in a vertical plane, the two meeting at and including a common linear axis and being oriented so the displays are at 90 degrees relative to each other, and each display providing a light output that is polarized in the same direction, e.g., from the lower left toward the upper right of the respective display, say at an angle of 45 degrees relative to horizontal or vertical (not considering sign). The beam splitter is oriented between the displays, has its plane (or an extension thereof) intersecting the linear axis mentioned, and is at an angle of 45 degrees relative to each display; and the beam splitter is so positioned relative to the two displays that one can be viewed directly through the beam splitter and the other can be viewed by reflected light from the beam splitter to provide a virtual image, e.g., a reflected image, of the latter display.

If the two displays are positioned with respect to the beam splitter such that the virtual image of one display is exactly superimposed on the other, the

beam splitter will reflect the angle of the polarization vector at right angles to the display which is not reflected. Consider as an example the polarization direction of light incident on the beam splitter intended for reflection to be represented by an arrow pointing in the direction of polarization; the reflected light from the beam splitter will present the mirror image of the arrow, and, therefore, the arrow will appear to a viewer to be at 90 degrees (crossed) relative to the original polarization of the incident light on the beam splitter (and, thus, also crossed relative to the polarization direction of light transmitted directly through the beam splitter from the other display). Therefore, the reflected image from the beam splitter and the direct image viewed through the beam splitter have linear polarization directions that are at right angles; and this can be accomplished without additional elements.

If an electronic signal is received corresponding to the left and right image, they can be displayed separately on the two liquid crystal display panels. They can be seen by the left and right eye in the proper order by using glasses which are linearly polarized at right angles to each other and parallel to the image that is intended for the left or right eye. One eye sees a display through the beam splitter and the other eye sees the other display by reflection from the beam splitter.

Although the invention is described using Liquid crystal displays (LCDs), it will be appreciated that the invention may use other displays or image generators, provided the light output from the displays is polarized or is given polarization characteristics, e.g., by using one or more polarizers in the light path. For convenience of description and to avoid adding unnecessary verbiage, the image generators or displays are considered and described herein as active matrix LCDs, but it will be appreciated that other displays or image generators may be used.

It may be desirable at times to use circular polarized light to separate the two images mentioned above. This can be done in several ways, two of which are mentioned here by way of example. The first is by putting quarter wave plates at both image generators, such as the LCDs, with their slow axis horizontal or vertical on each of the LCDs. More generally, the slow axis of the quarter wave plates is at 45 degrees to the polarization direction of linear

polarized light from the respective LCDs. This continues to maintain the same structure on both displays. When the circular polarized light is reflected from the beam splitter it reverses its sense; thus, right circular polarization becomes left circular polarization. A second way of achieving two circular polarizations is to place a quarter wave plate at the exit bezel or a location optically downstream of the two LCDs and beam splitter so that both the direct view image and the virtual image light go through the quarter wave plate and become circularly polarized. Thus, the slow axis is at 45 degrees to the two polarizations which were generated and provided by reflection or transmission at the beam splitter.

Circular polarizers are generally produced by bonding a quarter wave plate to a linear polarizer such that the linear polarizer is toward the observer . The quarter wave plate converts right-handed circular polarized light to linear polarized light, and it converts left-handed circular polarized light to linear polarized light, except the polarization directions of the two linear polarized lights are at right angles to each other. Since most circular polarizers which use quarter wave plates are tuned for green light, they are not perfect. In order to achieve a higher performance the circular polarizer may be mounted so that the polarized direction of the linear polarizer at the output is perpendicular to the linear polarization at the display for the nullification of the transmitted image. For the reflected image the direction should be parallel for the linear polarization at the polarizer and display respectively.

The information is presented to the displays of the invention such that the information in one display is a mirror image so that its reflection from the beam splitter is a normal image. This is normally done electronically but it can be accomplished by how the video signal is brought into the flat panel display. For displays that are mounted vertically the reflected display can be scanned from right to left instead of left to right. Depending upon the signal the video signal can be reversed either line at a time or frame at a time.

The invention has additional useful features. By displaying normal video images which are field sequential one field can be displayed on one display

and the other field on another, thus allowing a signal from both fields to be present at one time. This arrangement reduces motion artifacts since both fields are simultaneously displayed. The liquid crystal display continuously holds the image until it is changed. This also makes possible the display of HDTV images which are based on field sequential at half the bandwidth in each display. A further advantage in this form of mixing is an improvement in the color separation. The color in many flat panel displays is based on vertical lines of red, green, blue and white. When they are reflected they go from white blue green and red thus giving a different order to the colors in reflection. This reduces color borders and other artifacts caused by the color sequence above.

The present invention has the ability to display images in three dimensions and also has the ability to improve the resolution and color artifacts of flat panel monitors.

Referring to the drawings wherein like reference numerals designate like parts in the several figures, and initially to Fig. 1, a monitor for showing high-resolution and three-dimensional images is generally illustrated at 10 being viewed by an individual 11 as a viewer of images provided or shown by the monitor. As used herein, the term "monitor" may include a system of several displays, a system of several displays and associated circuitry and/or software, etc. and/or a single display–for shorthand convenience any of these terms and functions may be used equivalently and interchangeably with distinctions, if appropriate, being provided by context. The monitor 10 includes a pair of liquid crystal displays 12a, 12b and a pair of linear polarizers 13a, 13b. The displays 12a, 12b may have integral polarizers, as in active matrix displays, in which case separate polarizers 13a, 13b would be unnecessary. The displays 12a, 12b and polarizers 13a, 13b provide linear polarized light images to a beam splitter 14 of the monitor 10. The image from the display 12a and polarizer 13a is viewed directly by the viewer 11 as light therefrom is transmitted directly through the beam splitter 14. The image from the display 12b and polarizer 13b is reflected by the beam splitter toward the viewer 11; the direction of polarization of the linear polarized light provided from the display 12b and polarizer 13b is rotated 90 degrees due to the mirror image effect described above so that the light 15 reaching the viewer 11 includes two images, one

from each display 12a, 12b and the polarization directions of the linear polarized light representing such images are crossed, e.g., at 90 degrees to each other, as was described above. The viewer 11 uses linear (plane) polarizers 16a, 16b to view by his or her eyes 17a, 17b the left and right eye images from the monitor 10. The polarizer 16a, for example, transmits linear polarized light from a respective display, e.g., display 12a, which is intended to be viewed by the left eye of the viewer; and the polarizer 16b, for example, transmits linear polarized light from the other display, e.g, display 12b, providing the right eye image to the right eye of the viewer 11. The beam splitter 14 is shown as a prism beam splitter, but it will be appreciated that other types of beam splitters may be used; many are well known in the art.

It will be appreciated that the monitor 10 of Fig. 1 has its parts arranged as was described above. For example, the displays 12a, 12b may be flat panel displays which are arranged in a vertical, horizontal, or some other common direction, and the planes thereof are parallel with an imaginary linear axis 18 which extends in a direction perpendicular to the plane of the drawing relative to the illustration of Fig. 1. Also, the eyes of the viewer 11 are shown somewhat in perspective relative to the drawing, as they typically would be aligned in parallel with the axis 18 for optimum viewing, although some off-axis alignment may be acceptable.

An image signal source 19 is illustrated. Such source may be a video source, a computer, a tape player or CD Rom player, etc. The image signal source may be remote and the image signal may be provided via a network or the like. The image signal source provides signals to the displays 12a, 12b as a usual video circuit or video card provides signals to a display to create images for viewing. If desired, the image signal source 19 may include circuitry for reversing the direction of scanning or reversing the image being provided to a respective display, as was mentioned above.

Turning to Fig. 2, another monitor for showing high-resolution and three-dimensional images is illustrated generally at 20. The monitor 20 is similar to the monitor 10, except the monitor 20 uses circular polarized light. Accordingly,

respective quarter wave plates 21a, 21b are provided to convert linear polarized light from the respective displays 12a, 12b and, if used, linear polarizers 13a, 13b, to circular polarized light. The light output 15' may include both left and right circular polarized light, and the circular polarizers 16a', 16b' respectively transmit one or the other of such left or right circular polarized light to respective eyes 17a, 17b of the viewer 11 for viewing respective left and right eye images. Although the direction of circular polarization of light incident on the beam splitter from the two displays 12a, 12b may be the same, the beam splitter reverses the direction of circular polarization of the light it reflects from the display 12b, as was described above. The circular polarizers 16a', 16b' can distinguish or discriminate between the left and right circular polarized light to provide respective images to the eyes 17a, 17b of the viewer 11.

Referring briefly to Fig. 3, another monitor for showing high-resolution and three-dimensional images is illustrated generally at 30. The monitor 30 is similar to the monitor 20, except the monitor 30 uses only one quarter wave plate 21' to obtain both left and right circular polarized light from the respective linear polarized light inputs thereto from the displays 12a, 12b, linear polarizers 13a, 13b (if used), and beam splitter 14. The quarter wave plate is arranged relative to the polarizers 13a, 13b or the direction of linear polarized light so the slow axis is at 45 degrees relative to the direction or plane of such linear polarization.

Turning to Fig. 4, 5 and 6 a packaged monitor for showing high-resolution and three-dimensional images and, alternatively, for showing multiple images in parallel, is shown generally at 40. In Fig. 4 the monitor 40 is in closed condition; in Fig. 5 the monitor 40 is in partly open condition; and in Fig. 6 the monitor 40 is in full open condition. The monitor 40 includes a hinge 41 relative to which the displays 12a, 12b, linear polarizers 13a, 13b, and beam splitter 14 are mounted. In Fig. 4 those components are pivoted on or relative to the hinge 41 and to each other to assume a relative compact nested arrangement, e.g., for storage in a minimum space. A protective cover or package 42, including cover portions 42a, 42b, possibly hinged at 41', as illustrated in Fig. 4, may be placed over those components to avoid damage while in stored condition. Connections 19' may be provided to couple the

displays to an image signal source or, if desired, the image signal source may be appropriately mounted in the package 42.

As is illustrated in Fig. 5, the monitor 40 includes the displays 12a, 12b, linear polarizers 13a, 13b (and quarter wave plates, if used), and beam splitter 14 arranged in partially open condition relative to the stored condition; this partially open condition is obtained by rotation or pivoting relative to the hinge 41. If desired appropriate stops may be used to help align the components relative to each other in orientation similar to that described above with respect to Figs. 1-3.

As is illustrated in Fig. 6, the monitor 40 includes the displays 12a, 12b, linear polarizers 13a, 13b (and quarter wave plates, if used), and beam splitter 14 arranged in fully open condition relative to the stored condition; this fully open condition has the displays 12a, 12b oriented in adjacent parallel relation so both can be viewed side by side to present increased amount of information to the viewer. Such orientation is obtained by rotation or pivoting relative to the hinge 41. If desired appropriate stops may be used to help align the components relative to each other as illustrated in Fig. 6.

Thus, it will be appreciated that the monitor 40 may be used to provide either stereo views or large area mono views of respective images. Furthermore, the invention provides a device for not only displaying three dimensions but also improving the resolution and color artifacts of flat panel monitors.

The various methods of using the invention are described above. Summarizing, though, it will be appreciated that using the invention, e.g., as illustrated in Figs. 1-3 and 5, two images are provided and can be discriminated by polarization characteristics to obtain respective images for viewing. The two images may be provided simultaneously without the need to provide frame or field sequential images or time sequential images (e.g., one image for viewing by one eye and the next image or viewing by the other eye, and so forth); thus, increased resolution and reduction of flicker can be obtained. Further, if desired, using the invention as illustrated in Fig. 6, large area display may be

obtained by displaying respective images on adjacent displays 12a, 12b, for example.

Turning to Fig. 7, a system for implementing the invention is illustrated at 50. The system 50 includes a display 51, such as the monitors 10, 20, 30, 40 described above. The system 50 also includes an image signal source 52 to provide appropriate signals to the display 51 to create images for viewing. The image signal source 52 includes, for example, a computer 53 and an image source 54. The image source 54 contains information or provides information to the computer 53 which supplies signals to the display 51 to create images for viewing. The image source may be, for example, a video source, a tape player, a CD-ROM player, a connection to a network to receive signals from a remote device, or a computer program, for example, which is operable on the computer 53 to develop images, such as for playing a game, for presenting architectural or mechanical drawings, etc. Also associated with the computer 53 are input devices 54, such as a keyboard, mouse, pointing device, or some other input signal providing mechanism to provide inputs to the computer to operate the same in a desired fashion.

The computer 53 includes a processor 55 and a memory 56. The processor may be a conventional microprocessor, such as, for example, one from Advance Micro Devices sold under the trademark ATHALON or one sold under the trademark K-6, a microprocessor sold by Intel Corporation under the trademark PENTIUM, or another processor. The memory 56 may include non-volatile memory, such as ROM, CD-ROM, DVD, etc. and/or volatile memory, such as random access memory. Portions of the memory 56 may be designated as illustrated as a frame grabber 57 and as a frame buffer 58.

It will be appreciated that the several parts of the computer 53 described herein are exemplary. Other components, such as processors, memories, input/output devices, commonly used, currently available, and/or that may be developed in the future may be used to carry out various functions disclosed and described herein in accordance with the present invention and, thus, are equivalents of the illustrated and described exemplary embodiment.

Signals representing an image or characteristics of an image are provided the processor 55. Those signals may be supplied via the image

source 54 or, if desired, the image source 54 may be part of the memory 56, such as a CD-ROM, DVD or some other device included in or coupled to the computer 53 to provide the image information. In many display systems images are presented on a display, such as the display 51, as a series of sequentially presented frames. Signals representing a given frame, say from the image source 54, may be provided by the processor 55 to a frame grabber 57. The frame grabber may be a portion of the memory 56 selected to grab or to accumulate the information related to a given image frame. If the image signals include stereoscopic images, for example, a left image and a right image, sometimes referred to as a stereo pair, the frame grabber 57 may include two respective portions, one for grabbing and storing the left image and one for grabbing and storing the right image of a given frame or pair of frames for a given stereoscopic image. The frame buffer 58 is provided with the image signals, for example, on a bit mapped basis, and supplies those signals via the processor 55 to the display 51 for viewing by a viewer. The frame buffer 58 may include two portions, for example, one that stores the left image and one that stores the right image, and the processor directs the respective image information to the respective displays 12a, 12b (Fig. 1), for example.

Summarizing operation of the system 50, the processor 55 receives the image signals from an image source and supplies corresponding data representing a given frame or pair of frames to the image grabber 57. When the data representing a given image or pair of images (left and right images) in the frame grabber 57 has been completed, the processor stores the frame data in the frame buffer 58 and from the frame buffer 58 the processor either directly or via an appropriate output circuitry, such as a VGA card or the like, to the display 51 for presentation to and viewing by a viewer 11. Various techniques may be used to obtain the image data and to provide it to the frame buffer 58. It may be unnecessary to use a frame grabber 57 in which case the image data may be supplied from some image source 54 via the processor 55 directly to the frame buffer, for example. Other devices may be used, too, to obtain image data, to process the data and to provide it to the display 51, the computer 53

being only one example of such a device and method.

As was mentioned above, the image provided by the display 12b (Figs. 1, 2 and 3) is reflected by the beam splitter 14 and provided as part of the output light 15. Such reflected image in a sense is a virtual image because it is reversed due to the reflection by the beam splitter. Also, as was mentioned above, the image presented by the display 12b is inverted so that when it is reflected by the beam splitter 14, the reflected virtual image and the image from the display 12a, which is transmitted through the beam splitter 14 will be substantially superimposed in proper relation to allow viewing of a stereoscopic image by a viewer 11. Such inverting of the image presented by the display 12b may be accomplished in a number of different ways, several of which are described here and others which may be equivalents also may be used. For example, the device which obtains the image data for the display 12b, such as a video camera, charge coupled device (CCD), etc., may be operated to perform its scanning in the reverse direction relative to the usual direction of scanning so that the data provided the frame buffer 58 and the display 12b when presented in the usual scan direction would be reversed. Alternatively, the image data provided the frame buffer 58 by the processor 55 for delivery to the display 12b may be inverted electronically prior to being stored in the frame buffer 58. In the latter case, an example would include the frame grabber 57 receiving image data for the left image and right image of a given frame and that data subsequently is stored in the frame buffer 58, but prior to being stored in the frame buffer 58, the image data for one of the frames is inverted. A further possibility is to store the image data for the left and right images of a given frame in the frame buffer 58 and when delivering that data to the respective displays 12a, 12b, inverting the data provided to the display 12b essentially in real time as it is provided thereto.

The image inverting described above is shown schematically in Figures 8A, 8B and 8C. Fig. 8A is similar to Fig. 1 showing the monitor 10, displays 12a, 12b, and the beam splitter 14. Fig. 8B is a plan view of the display 12a as it is seen by the viewer 11. The top 70a of the display 12a is at the right hand side of the illustration in Fig. 8B. Relative to the point of view of the viewer 11 looking at the monitor 10 and seeing through the beam splitter 14 the image

presented by the display 12a, a point, pixel, component of the image, etc., at the upper left corner of the display 12a is represented by a solid line circle 71a. In Fig. 8B the direction of scanning image data or providing the image data to the display 12a is represented by the arrows 72a. Although the providing of image data to a given line 73a, 74a, etc., of the display 12a is referred to as a scan direction, in many liquid crystal display devices all of the image data is presented to a given line at a single time. All the image data to an entire display may be provided simultaneously or substantially simultaneously directly from the frame buffer. Direction of scan, though, sometimes is referred to with respect to some CRT (cathode ray tube) devices. Regardless of how the data is presented, though the data at the location 71a of the display 12a is seen at the upper left corner of it as viewed by the viewer 11. The data or image representing the data at a location 75a is seen part way across the scan line, line of pixels, etc., of the display 12a near the top 70a thereof. Other data also may be provided to pixels of the display 12a to present image information for viewing by the viewer 11.

To demonstrate the reversing of the image information presenting on the display 12b, the display 12b is shown in Fig. 8C in parallel with the display 12a of Fig. 8B. Thus, Fig. 8C is a plan view of the display 12b from Fig. 8A, but such plan view is rotated 90 degrees in the direction of the arrows 8C--8C, e.g., about the axis 18. The top of the display 12b is identified 70b for convenient reference in Figs. 8A and 8C for relational correspondence generally with the top 70a of the display 12a in Figs. 8A and 8B. An image point 71b shown on the display 12b is provided on the top right of the display 12b. A virtual image view, i.e., the reflection from the beam splitter 14 will in effect make the point 71b appear somewhat superimposed or somewhat coincident but nevertheless somewhat shifted for stereoscopic imaging and viewing, relative to the image point 71a of the display 12a. Scanning of the image data or providing of the image data to the display 12b is in accordance with the direction of the arrows and lines 72b, 73b and 74b. It will be appreciated that such scanned direction or presenting of data is in effect inverted or opposite to the direction in which

data is provided the display 12a (Fig. 8B). If the image data to the display 12b were not so inverted or reversed, the image point 71b would appear at location 76 in the display 12b (as is seen in Figs. 8A and 8C) and, thus, would not coincide for a proper image presentation with a image point 71a of the display 12a.

As was described above, various techniques can be used to invert or to reverse the image data to obtain the desired stereoscopic image.

It will be appreciated that although the invention is described above with respect to flat panel display devices of the liquid crystal type, the invention may be used with other displays. However, if the displays do not have flat characteristics, the advantages of alignment, reflection minimization, and other features of flat panel display technology would not necessarily be available.

As was mentioned above, too, exemplary active matrix flat panel displays typically are rectangular and, for example, if relatively square, have the polarization axis of the output light at approximately 45 degrees to an edge of the display. This arrangement facilitates alignments of the various components hereof as was mentioned above. However, if desired, other polarization alignments may be employed and, if necessary, accounted for to enable discrimination between respective left and right images.

Although the beam splitter 14 is shown in Figs. 1-3 as a prism type beam splitter device, it will be appreciated that other types of beam splitters may be used. An example is a glass plate, a sheet material that is semi-transparent and semi-reflective, or some other device that is able to transmit light from the respective displays for viewing by a viewer 11.

The images displayed by the display 12a, 12b may be presented to the viewer 11 simultaneously without the need for field sequential operation. Therefore, a high resolution image with minimal or substantially no perceptible flicker may be presented to the viewer and in such an embodiment, since all image data may be presented substantially simultaneously to and/or displayed by both displays, very high resolution is possible.

From the foregoing, then, it will be appreciated that the monitors 10, 20, 30 of the invention provide a display system useful to present stereoscopic or monoscopic images for viewing.

The images may be provided the displays 12a, 12b (sometimes referred to as display generators or as image generators) as stereo pairs. A stereo pair is a pair of images which, respectively, represent the left eye and right eye views of an image. The image data representing two images of the stereo pair may be provided to the frame buffer, for example, for temporary storage and delivery to the respective displays 12a, 12b. In some prior devices the left and right images are provided sequentially to a common display, and the sequential images are discriminated and provided for viewing to respective eyes of a viewer. In the present invention, though, the left and right images may be shown either sequentially, one on one display and one on the other display, or the left image may be shown on one display while the right image is shown on the other display. In prior display systems which use a common display to show sequentially left and right images, there may be a loss of some data that is displayed to the viewer, for example, due to various techniques employed to deliver data and to display images representing the data. The present invention allows all data for one image of a stereo pair to be presented the viewer and all data from the other image to be presented to the viewer, thus enhancing resolution, clarity, brightness, and other characteristics of the viewed image relative to the prior stereo display systems. The invention also increases the amount of information that can be provided/displayed to the viewer.

It will be appreciated that the two display generators are arranged at right angles to each other. In the illustrated embodiments shown in the drawings those display generators are in vertical planes that are perpendicular to each other and intersect at the axis 18. However, if desired, one display generator or image generator may be in a vertical plane and the other in a horizontal plane, e.g., above or below the display generator which is in the vertical plane. In such case adjustment may be made to the arrangement of the beam splitter so both images can be viewed in substantially superposed relation but with appropriate offset in the respective images provided by the image data thereof to obtain stereoscopic views. Also, in such case it may be necessary to alter the manner in which the image data to one of the display

generators is inverted relative to the image data provided the other display generator to obtain proper image superpositioning.

The arrangement of the display generators 12a, 12b is such that the two are perpendicular, and with the beam splitter cooperative therewith the images are provided along a common light path toward an output of the monitor(s) of the invention for viewing as described above.

Briefly referring to Fig. 9, an embodiment of display system 80 according to the invention is illustrated. The display system 80 includes a monitor, such as one of the monitors 10, 20, 30 described above. A cubical structure 81 having an open interior and at least three open sides 82, 83, 84 provides for alignment of and/or support of the displays 12a, 12b (associated polarizers (not shown)), and the beam splitter 14. In the display system 80 the top and bottom 85, 86 are open (or either or both may be closed, as desired) and the side 87 includes a light absorbing material to absorb light 88 from the displays which is not intended for viewing. Such absorbed light is that provided by the display 12a and reflected by the beam splitter and that provided by the display 12b and transmitted by the beam splitter. Therefore, such light tends not to interfere with the viewed image received by the viewer 11 (Fig. 1). The cubical structure 81 may be a plastic, metal or other material. It may include a number of arms, frame members, etc., which are coupled together in relation to each other to obtain the form illustrated. The displays 12a, 12b may be positioned relative to the structure 81 or may be positioned in windowed openings 91, 92 in the respective open sides 82, 83. The windowed opening 93 in the front side 84 allows viewing of the beam splitter and light from the displays 12a, 12b, which is combined by the beam splitter to be provided as output light along a common light path 95 which may be viewed by the viewer to obtain a desired stereoscopic image.

Referring to Figs. 10–15, an embodiment of monitor 100 that embodies the various features of the invention described above is illustrated. The monitor 100 includes a pair of displays 101, 102 that are oriented at an angle relative to each other generally in a manner described above, and a beam splitter 103 at the bisectrix of the angle. In Fig. 10 the angle is represented by the letter A. The angle A is an obtuse angle as it is illustrated in Fig. 10. The obtuse angle

may be greater than 90° up to 180°. In several examples, the obtuse angle may be from greater than 90° to approximately 170°. In another example the obtuse angle may be from about 100° to about 150°. In another example the obtuse angle may be on the order of approximately 110° to 140°. The obtuse angle may be on the order of approximately 120°.

In Fig. 10 a mount 104 is illustrated for mounting and supporting displays 101, 102 and the beam splitter 103 in relation to each other. An exemplary mount includes a base 105 and a mounting bar or strap 106. The base and strap have adequate strength, stiffness and other appropriate mechanical characteristics to hold the displays and beam splitter in relation to each other at, for example, the illustrated obtuse angle A relation, at a 90° relation, such as that described with respect to a number of the embodiments above, etc. The strap 106 may be attached to the base 105 by a fitting 107.

In Fig. 10 a hinge 108 is illustrated schematically. The hinge 108 may provide support for the beam splitter 103 from the strap 106. The hinge 108 also may be a point about which one portion 106a of the strap 106 may be pivoted relative to the other portion 106b of the strap 106.

The displays 101, 102 illustrated in Fig. 10, for example, and the displays described above, may be flat panel displays, liquid crystal displays, etc. The displays themselves or in conjunction with polarizers or the like provide polarized light outputs as was described above.

The two displays 101, 102, or other pairs of displays used in the several embodiments hereof, may have the following characteristics. For example, they may have the same aspect ratio and the same resolution. Resolution may be, for example, considered in pixels or dots per inch, examples being 72 dots per inch, 188 dots per inch, 288 dots per inch, etc. Thus, the displays 101, 102 may have the same spatial resolution or digital resolution. The physical size of the two displays 101, 102 may be the same or they may be different from each other. The polarization characteristics of the displays 101, 102 are the same, as was described above. Thus, as an example, with reference to Fig. 12 where the faces of both displays 101, 102 can be seen, each display has a pair of

opposite edges, for example, 101e, 101e' and 102e, 102e'. Consider a direction parallel to the hinge 108 extending across the face of each display 101, 102 from the respective edges 101e, 101e' and 102e, 102e', as is represented by lines 109, 110 in Fig. 12. The direction of polarization of plane polarized light from the respective displays 101, 102 is at a 45° angle to the respective lines 109, 110, as is schematically represented at lines 111, 112 in Fig. 12. Therefore as was described above, a person viewing the display 102 through the beam splitter 103 will see an image from the display 102 formed by light having a linear polarization in the direction of the line 112. The viewer would see the image from the display 101 as light reflected from the beam splitter 103, and the direction of polarization of linear polarized light of such image is crossed, i.e., is rotated to be at 90° relative to the direction of polarization represented by line 112 of the image provided by the display 102. Thus, operation of the monitor 100 is like the operation of the monitors described above in accordance with the invention. Due to the relationship of polarization directions and the relative positioning of the beam splitter to the displays, e.g., at the bisectrix of the angle between the two displays, polarization direction of reflected light is rotated by the beam splitter, as was described above. Also, circular polarized light may be used in the manner described above.

The beam splitter 103 may include an anti-reflecting coating (sometimes referred to as anti-reflective coating) on the surface thereof opposite the surface that effects the light reflecting function of the beam splitter. Various anti-reflecting coatings and processes are available. Also, various techniques are known to provide for light reflection from a desired surface of a beam splitter, for example, a beam splitter in the form of a sheet-like material such as that illustrated in Figs. 1015. The beam splitter 103 also may be of the non-polarizing type in that it does not affect polarization of light; such beam splitters sometimes are referred to as polarization neutral beam splitters. The beam splitter 103, for example, may change the direction of light propagation by reflecting the light, but it does not affect polarization. The beam splitter does function to rotate the plane of polarization or to change the sense of circular

polarized light in the manner described above, though. Thus, it will be appreciated that the beam splitter 103, as well as the beam splitters described elsewhere herein in connection with the other illustrations of the invention, may be considered an engine or the device or operative instrument that effects the rotating of the plane of polarization of the reflected light while transmitting without affecting the plane of polarization the transmitted light from the respective displays so that light from the respective displays can travel along a common light path to be viewed by a person who is using polarized lenses (reference to "lenses" includes actual lenses, and also includes polarizers, analyzers, eye glasses containing same, etc.) to separate the two images based on respective polarization characteristics. Such operation by the beam splitter 103 is effected without regard to whether the light is plane polarized or circular polarized, as was described above.

In the illustrations of the monitor 100 of Figs. 10–15, it will be appreciated that the arrangement of the displays 101, 102 and the beam splitter 103 is an over and under type of arrangement rather than a side-by-side arrangement illustrated in Fig. 9, for example and in other figures described above. As an example, over and under is indicative of one display being vertically above the other, but otherwise arranged generally in the manner described above. The various features of the invention described in the several embodiments, whether the displays are side-by-side, over and under, or in some other arrangement, are useful in the several embodiments. It also will be appreciated that other arrangements of the displays may be provided, such as, for example, a generally vertically oriented display and one that is beneath it, e.g., opposite the arrangement shown in Figs. 10–15, or in some other arrangement.

Briefly referring to Fig. 16, as was mentioned above, in the monitor 200 the physical size or display area of displays 201, 202 (or other pairs of displays described above) are different. The arrangement of the displays and the beam splitter in such case, though, still would embody the arrangements described above with respect to the displays being at an angle relative to each other, the

beam splitter at the bisectrix of the angle and the displays being viewable so that a viewer can see one display through the beam splitter and see the other display be reflection from the beam splitter. The polarization characteristics would be as described above. With the displays being of different physical sizes, though, a window effect (sometimes referred to as "windowed") may be achieved whereby, for example, a stereo image is seen in a small portion of the overall viewed area by a person viewing such a display. In the illustrated example of such an embodiment in Fig. 17 a relatively large display 201 and a relatively smaller display 202 are illustrated at an angle of approximately 90° or greater, for example, an obtuse angle, relative to each other. A beam splitter 203 is positioned at the bisectrix of an angle A. Thus, an observer having polarized glasses shown at 204 may look at the images from the monitor 200 of Fig. 17 and see a large image on the display 201 or one or more images on the display 201 and also may see a stereo image formed in the area 205 by the two displays 201, 202 and beam splitter 203, whereby the area 205 may appear as a window.

Turning to Figs. 17 and 18, a monitor 220 is illustrated. The monitor 220 includes a display 221 and a beam splitter 222. The display 221 is analogous to the arrangement of displays 40 shown in Fig. 6 whereby two displays are oriented in parallel, e.g., whereby the angle between them is 180°. In Figs. 17 and 18 the display 221 is a single display (or it may be two displays as in Fig. 6), and the direction or plane of polarization is at 45° to an edge, such as an edge 223, the polarization being represented by the lines 224, for example. The polarization direction is referenced to the edge 223 for convenience of description. However, it will be appreciated that such configuration presumes that the beam splitter is oriented as shown. The relation of the polarization direction actually is determined relative to the beam splitter or to the actual or imaginary axis mentioned above to obtain rotation of polarization direction of light by reflection from the beam splitter. Thus, the display 221 is analogous to a display having two parts 221a, 222b that are at an obtuse angle A, which is 180°. The beam splitter 222 is at the bisectrix of the obtuse angle A.

A person may view the monitor 220 via a pair of polarized lenses 225 such that the lenses are polarized at 90° to allow light from a left eye image to reach the left eye and light from a right eye image to reach the right eye. Alternatively, the polarized lenses 225 may be circularly polarized, and the light reaching the lenses would be circularly polarized for discriminating between left and right eye images of a stereo pair provided by the monitor 220, generally as was described above.

Light from the display portion 221a can be seen by looking through the beam splitter 222. Light from the display portion 221b may be viewed by reflection from the beam splitter. When the light reflects from the beam splitter 222, the direction of polarization is rotated 90°. Therefore, images from the respective display portions 221a, 221b may be viewed along a common light path 230, and the images may be separated by optical polarization characteristics using the polarizers 225. If the light is linear polarized, then the polarized lenses 225 would be linear polarized and crossed by 90°; if circular polarized light is used then the polarizers 225 would be circular polarizers having opposite sense, as was described above.

Thus, the monitor 220 provides an easy approach to obtaining a 3-D image using a single display. Driving circuitry 231 may be associated with the display 221 so that the image provided at respective display portions 221a, 221b are a stereo pair.

Although the invention has been shown and described with respect to a certain preferred embodiment or embodiments, equivalent alterations and modifications will occur to others skilled in the art upon reading and understanding this specification and the annexed drawings. In particular regard to the various functions performed by the above described integers (components, assemblies, devices, compositions, etc.), the terms (including a reference to a "means") used to describe such integers are intended to correspond, unless otherwise indicated, to any integer which performs the specified function of the described integer (i.e., that is functionally equivalent), even though not structurally equivalent to the disclosed structure which

performs the function in the illustrated exemplary embodiment or embodiments of the invention. In addition, while a particular feature of the invention may have been described above with respect to only one of several illustrated embodiments, such feature may be combined with one or more other features of the other embodiments, as may be desired and advantageous for any given or particular application.

It will be appreciated that portions of the present invention can be implemented in hardware, software, firmware, or a combination thereof. In the described embodiment(s), a number of the steps or methods may be implemented in software or firmware that is stored in a memory and that is executed by a suitable instruction execution system. If implemented in hardware, for example, as in an alternative embodiment, implementation may be with any or a combination of the following technologies, which are all well known in the art: discrete logic circuit(s) having logic gates for implementing logic functions upon data signals, application specific integrated circuit(s) (ASIC) having appropriate combinational logic gates, programmable gate array(s) (PGA), field programmable gate array(s) (FPGA), *etc.*

Any process or method descriptions or blocks in flow charts may be understood as representing modules, segments, or portions of code which include one or more executable instructions for implementing specific logical functions or steps in the process, and alternate implementations are included within the scope of the preferred embodiment of the present invention in which functions may be executed out of order from that shown or discussed, including substantially concurrently or in reverse order, depending on the functionality involved, as would be understood by those reasonably skilled in the art of the present invention.

The above description and accompanying drawings depict the various features of the invention. It will be appreciated that the appropriate computer code could be prepared by a person who has ordinary skill in the art to carry out the various steps and procedures described above and illustrated in the drawings. It also will be appreciated that the various terminals, computers, servers, networks and the like described above may be virtually any type and

that the computer code may be prepared to carry out the invention using such apparatus in accordance with the disclosure hereof.

INDUSTRIAL APPLICATION

The present invention may be used to provide stereoscopic (three dimensional) or monoscopic (two dimensional) images for viewing and/or for other use.